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E. L. OVERHOLSER[1]

Pollination requirements of apple varieties have received much attention from a number of workers in the United States. Among those who have studied the problem are Waugh (1898), Waite (1899), Powell (1902), Lewis and Vincent (1909), Wicks (1918), Gowan (1920), Vincent (1920), Morris (1921), Auchter (1922), Crandall (1922), and MacDaniels (1926). Because of the fact that their reports are not always in agreement, that the pollination requirements of individual varieties may differ in the several sections of the country, (Tufts and Philp, 1923), and that several varieties grown in California have not previously received much attention, the studies recorded in this paper were undertaken.

The Yellow Newtown and the Yellow Bellflower, both in the Pajaro Valley, and the Gravenstein in the Sebastopol section are the principal varieties grown in California. While the Yellow Bellflower and Gravenstein generally bloom profusely, they sometimes fail to develop commercial crops. On the other hand, even when planted in separate blocks, they frequently set fair crops of fruit.

In the coastal counties of California where the studies were conducted, the blooming period of apples is relatively long, being sometimes six or eight weeks in duration. In the Mississippi Valley and the Northeast, it lasts only eight to ten days. Furthermore, under California weather conditions, insect activity is more likely to prevail during much of the blooming period. It appears, therefore, that in normal seasons, lack of proper varieties for cross-pollination is less serious in the coastal districts of California.

OBJECTS OF THE INVESTIGATION

Beginning in 1919, pollination studies were conducted over a period of four years in the vicinities of Watsonville and Sebastopol.[2] The object was chiefly to determine the pollination requirements of the Yellow Newtown, Yellow Bellflower, and Gravenstein; and incidentally to find out the part played by bees in effecting pollination, the relative time of blooming, and the abundance and the viability of the pollen

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produced. Attempts were made to discover satisfactory pollinizers for the three varieties mentioned and, in turn, the varieties that would pollinate them. In order to determine whether the results obtained from the experimental work were in agreement with the experience of growers, observations covering a period of two years were made in a number of orchards throughout the county where these varieties were available. Without exception the data obtained in the experiments were found to be in agreement with field experience.

All the trees utilized were in a healthy, well kept condition. The age of those at Watsonville was about 20 years, of those at Sebastopol, from 10 to 25 years. At Sebastopol the varieties employed were the Gravenstein, Delicious, Jonathan, Esopus (Spitzenburg), Baldwin, Tompkins King, Yellow Bellflower, and Rhode Island Greening; at Watsonville, the Yellow Newtown, Yellow Bellflower, White Winter Pearmain, and Red Pearmain.

In the study of the actual transfer of pollen thousands of hand pollinations were made. The results were then compared with the work of bees. Since the latter play such an important part in transporting pollen, it seems best to discuss this phase of the subject first.

The Use of Bees in Pollination.—The blossom of the apple, like that of most commercial deciduous fruits, is entomophilous, and supposedly requires insects, principally bees, for pollen transmission and pollination. Waugh (1898) and Lewis and Vincent (1909), by using microscope slides coated with vaseline and glycerine placed in the orchard, found that wind-carried pollen was inadequate for cross-pollination. Lewis and Vincent found that when 1500 blossoms on a seven-year-old apple tree were emasculated, only 5 fruits set. Apparently, no pollen was carried by wind from a profusely blooming tree twenty feet away. Moreover, no insects were attracted, because only the stigmas of the flowers remained.

Hendrickson (1916) found that insects may be necessary for the application of pollen with even self-fruitful varieties of plums, and Alderman (1918) found that placing of bees in an orchard increased the percentage of apple flowers setting fruit. More recently, Auchter (1922) found this to be true with apples in Maryland.

Following Hendrickson's method, tents made of light redwood and mosquito-bar were used to restrict bees to definite trees. The first and largest tent enclosed two trees, one a Yellow Newtown and the other a Yellow Bellflower. The second and third, which were small, were set over individual trees of each of these varieties. Under each tent was placed a hive of bees. Care was taken to leave no openings through which the insects might pass.

As checks, selected limbs of other trees of the two varieties were covered with mosquito-bar netting to exclude all insects. The remaining limbs upon the trees so utilized were left exposed and untreated.

The percentage of set of fruit on the trees and branches enclosed by mosquito-bar was determined by counting the total number of blossoms upon certain branches and recording the number of flowers on tags attached to each branch. Approximately, two months later, or after a set of fruit should have resulted, recounts were made and the percentage of set determined. For purposes of comparison, the percentage of natural set on untreated trees was obtained. The latter will be referred to hereafter as the "normal set." In most cases, approximately 5000 blossoms representing the total number on selected branches of six representative trees distributed throughout the orchard were counted each year. Later when they had developed, the fruits also were counted.

EXPERIMENTAL DATA WITH BEES

The first test of the value of bees in effecting cross-pollination in an apple orchard was made in the spring of 1919, at a time when the trees had a rather light bloom.

The various treatments and tests showing the relation between bees and pollination are shown in table 1.

TABLE 1

POLLINATION REQUIREMENTS OF THE YELLOW NEWTOWN AND YELLOW BELLFLOWER APPLE TREES AND THE VALUE OF BEES AS CARRIERS OF POLLEN

Variety and pollination treatment	Number of blossoms counted	Number of apples set	Per cent set
Newtown cross-pollinated by Bellflower (Under tent with bees.)	1794	918	51.50
Newtown self-pollinated (Under tent with bees.)	2046	381	18.62
Newtown wind-pollinated (Branches covered to exclude insects.)	1768	5	0.28
Newtown-normal set (Naturally pollinated by insects.)	1018	305	29.96
Bellflower cross-pollinated by Newtown (Under tent with bees.)	2709	108	4.31
Bellflower self-pollinated (Under tent with bees.)	2531	39	1.53
Bellflower wind-pollinated (Branches covered to exclude insects.)	958	3	0.31
Bellflower-normal set (Naturally pollinated by insects.)	481	77	16.00

The table yields the following information:

Bees play a prominent part in apple pollination.

The Yellow Bellflower does not set fruit well with its own pollen, even when bees are present in abundance.

The Yellow Newtown is fairly self-fertile but sets a much better crop when cross-pollinated by Yellow Bellflower.

Both the Yellow Newtown and Yellow Bellflower apparently set crops when the two are grown near each other in the orchard, provided insects (preferably bees) are present as pollen carriers. The conclusion seems justified that wind pollination is unreliable.

The Yellow Newtown and Yellow Bellflower seem to be able to pollinate each other if bees are present.

While the set of the tented Yellow Bellflower was increased when cross-pollinated with Yellow Newtown through the aid of bees, the set was only slightly over 4 per cent as contrasted with the normal set of 16.0 per cent resulting from open pollination in the orchard. This indicates that while the Yellow Bellflower pollinates the Yellow Newtown, the Yellow Newtown does not readily pollinate the Yellow Bellflower. In this connection, Hooper (1913) obtained evidence indicating that, while Bramley pistils and Cox Orange pollen were cross-compatible, Cox Orange pistils and Bramley pollen were cross-incompatible.

To investigate further the failure to set fruit when insects were excluded, another test was made in 1920. In 1919, the flowers from which insects were excluded were upon branches covered by mosquito-bar, while the rest of the tree was exposed to the visits of insects and hence could be cross-pollinated. Ewert (1906, 1907, 1909) appeared to find that parthenocarpic fruit, that is, fruit which forms without pollination, is at a disadvantage on the tree in competition with fruits containing developing seeds that result from cross-pollination. It was, therefore, considered that failure to set fruit on the branches from which insects were excluded might have resulted from this unfavorable competition. In the second test (1920), single entire trees of the Yellow Newtown and the Yellow Bellflower were separately covered with mosquito-bar tents to exclude insects. In addition, 2371 blossoms of Yellow Newtown and 2418 blossoms of Yellow Bellflower on ten trees of each variety, chosen at random, were covered with No. 10 Manila bags just before the petals had expanded sufficiently to expose the pistils and stamens. Occasional flowers, which were so far advanced as to expose the pistils and stamens, were removed. After the petals had fallen, the paper bags were removed. Not a single fruit set either under the tents or in the bags, notwithstanding the fact that the Yellow Newtown is self-fruitful. These data definitely

indicate that these varieties of apples under the conditions of the experiment did not set fruit except when the pollen was actually applied to the pistils by insects or by hand. This work is not in agreement with that of Auchter (1922) who found that no greater percentage of fruit set when pollen was applied with a brush than when bagged blossoms were unmolested.

Hand Pollinations.—To prevent possible chance pollination of the stigmatic surfaces with pollen of the same flower, the blossoms employed for the hand pollination experiments were emasculated after the flowers had expanded appreciably, but before the overlapping petals had parted or the stigmatic surfaces had become exposed and before the anthers had ruptured.

The emasculation, it was found, could be most expeditiously conducted by using the nails of the thumb and second finger to cut through the floral envelope, and then removing the stamens together with the petals and a part of the calyx-lobes, only the pistils being left. All flowers too far advanced or too immature or weak in their development were removed. This method with apples enabled a single worker to make from 1500 to 2000 emasculations daily and was more rapid than the use of scissors or forceps. The emasculated flowers were immediately covered by No. 10 Manila paper sacks, and the date and number of emasculated flowers recorded on a tag affixed to the bag and on record sheets.

With the Yellow Newtown, Yellow Bellflower, and Gravenstein varieties, from 20 to 25 trees in one to three orchards were used for each season's pollination work. With most of the other varieties, from 5 to 10 trees were used each season.

The flower clusters emasculated were on reasonably vigorous spurs, where it was expected conditions would be favorable for a reasonable percentage of flowers to set fruit. Between the time of emasculation and pollination, there was always some loss in the number of flowers, due to undetected injury during emasculation, or to some mechanical injury after emasculation. Such flowers were discarded at the time of pollination. The extent of this injury is evidenced by the fact that out of some 72,800 flowers emasculated, about 62,000 were in satisfactory condition for pollination, the loss being about 12 per cent.

Ewert (1907) states that the use of sacks in this manner subjects the enclosed spurs or portion of branch to unnatural conditions which may not be favorable for the setting of fruit. Heinicke (1917) found a larger percentage of Baldwin blossoms set fruit in translucent than in opaque sacks. He attributed this to the fact that the diffuse light

in the translucent sacks permitted some photosynthetic activiy, while nearly all light was excluded from the opaque sacks. Heinicke, however, in this experiment was troubled with aphid injury. The fact that aphids frequently cause apples to adhere which otherwise would abscise may have affected the results. Furthermore, the spurs were sacked in the spring before the clusters of flowers had separated and were not removed until late summer. In the pollination work, a week to ten days was generally the maximum period of time during which the blossoms and fruit remained bagged. Alderman (1918) and Vincent (1920) found little difference in the percentage of flowers which set in bags and on trees under frames covered with thin cloth.

Since insects appeared necessary to effect pollination of apples, and since Lewis and Vincent (1909) found that insects did not visit emasculated flowers, it was felt, in view of the opinions of Ewert and Heinicke, that to emasculate flowers and, after tagging the spurs and branches, to leave them exposed without covering with the paper sacks, would be of interest. When the emasculated and exposed pistils became receptive, the pollen was applied by hand, and the percentage of set compared with that from blossoms similarly treated but enclosed in the paper sacks.

After the work in 1920 and a second season's work in 1921, with an approximate total of 4000 emasculated, non-sacked blossoms of the Yellow Newtown and 4200 of the Yellow Bellflower, the non-sacking method was, under the conditions existing and the varieties tested, considered unsatisfactory.

Apparently, the emasculated blossoms dried out rapidly as a result of the wounded surfaces when not covered with sacks. The sacked blossoms did not dry out and their wounds healed readily. Furthermore, the blossoms which did not fall from excessive drying, seemed to have a shorter and less definite period, when the stigmatic surfaces indicated a receptive condition of the pistils. Sax (1922), on the other hand, seemed to find consistent results with uncovered, emasculated apple flowers in Maine, and apparently considered the method satisfactory.

Collection of Pollen.—A supply of pollen was obtained by collecting the advanced but as yet unopened flowers of each variety a day or so before the dried pollen was needed. The unopened anthers were removed with forceps from the rest of the floral parts and deposited in Petri dishes with the lids partially raised so as to permit aeration and slight air circulation to aid in the drying. The anthers were dried in reduced sunlight, or occasionally during cloudy weather,

in an incubator at a temperature of 27° to 30° C. When dry the anthers and any escaped pollen were placed in small glass vials which were loosely plugged with cotton and were kept in a dry place until ready for use.

Application of Pollen to Pistils. The flowers were hand-pollinated from one to three days after emasculation. The stigmas were found to be in a receptive condition after this interval of time. While the common practice in dusting the stigmas with pollen is to use a camel's hair brush, it was found more satisfactory in this case to use the end of a cork stopper to which the pollen adhered as a fine coating of yellow powder. Occasionally the anthers had to be broken up with a pencil and the vial shaken.

At the time of pollination, a count of the blossoms actually pollinated was made and the number noted on the tags and record sheets. The sacks were again placed over the clusters. When the fruits were sufficiently advanced to indicate that development would continue, the sacks were permanently removed and the number of the young fruits recorded. This count of apples was compared with the number of blossoms originally pollinated and the percentage of set thus determined. The percentage of set resulting from hand-pollinations was always compared with the "normal set" from flowers untreated and exposed to orchard conditions and the visits of insects.

The viability of each lot of pollen employed in the hand-pollinations was determined by germination tests in 10 to 12 per cent cane sugar solutions for from 24 to 36 hours at room temperature.

EXPERIMENTAL DATA WITH HAND-POLLINATIONS

In the presentation of the data, each of the more important varieties and crosses made are given in separate tables, and the data discussed under the variety heading.

Yellow Newtown.—The data obtained with the Yellow Newtown are given in table 2. The average set of the Yellow Newtown for three years when self-pollinated was about 12 per cent, as contrasted with the normal set during the same period of 19.5 per cent, which indicated the variety to be largely self-fruitful. This agrees with the work of Lewis and Vincent (1909) in Oregon. The work of Morris (1921) in Washington, and Vincent (1920) in Idaho, indicated the Newtown to be largely self-unfruitful. These workers, however, simply covered the blossoms and did not actually apply the pollen. The data previously presented indicate that such a method may not be a satisfactory one for determining self-unfruitfulness.

The Yellow Bellflower, upon the basis of three years' work, appeared to be a satisfactory pollinizer for the Yellow Newtown, giving a set of nearly 31 per cent, as contrasted with the normal set of 19.5 per cent. While Red Pearmain pollen appeared to be cross-compatible upon Yellow Newtown stigmas, it possessed no especial

TABLE 2

YELLOW NEWTOWN HAND-POLLINATION EXPERIMENTS (Watsonville)

Pollen variety	Years inclusive	Number flowers pollinated	Per cent set	Per cent normal set	Per cent pollen germinated
Self-pollinated	1919–21	3390	12.22	19.56	70
Yellow Bellflower	1919–21	2797	30.76	19.56	66
Red Pearmain	1920–21	827	12.81	14.41	65
White Winter Pearmain	1920–21	1103	18.93	14.41	75

merit as a pollinizer, since it gave a percentage of set less than the normal set. This was also essentially true of the White Winter Pearmain, although it gave a somewhat higher set than normal for the two years. The latter, therefore, may be considered satisfactory as a pollinizer of the Yellow Newtown.

Yellow Bellflower—The data in table 3 with 4328 self-pollinations again show the Yellow Bellflower to be self-unfruitful. Furthermore,

TABLE 3

YELLOW BELLFLOWER POLLINATION EXPERIMENTS (Watsonville and Sebastopol)

Pollen variety	Years inclusive	Number flowers pollinated	Per cent set	Per cent normal set	Per cent pollen germinated
Self-pollinated	1919–23	4328	0.07	8.5	74
Yellow Newtown	1919–23	4445	4.29	8.5	79
Red Pearmain	1920–21	1080	0.77	6.6	67
White Winter Pearmain	1920–21	1086	0.85	6.6	72
Gravenstein	1922–23	899	0.00	6.6	25
Jonathan	1922	736	0.08	11.4	75
Tompkins King	1922–23	883	0.00	6.6	22
Esopus	1922	1037	0.00	11.4	90
Rhode Island Greening	1922	965	0.00	11.4	40
Delicious	1923	163	3.00	1.9	50

the only pollen which appeared to give a set greater than the normal was the Delicious. The number of blossoms employed with Delicious pollen, however, was small (163), and the cross was made only one season. In addition, while the set with Delicious of 3.0 per cent

seemingly was not large, the normal set was relatively small, 1.9 per cent. When the Yellow Bellflower was cross-pollinated with Yellow Newtown the average set for three years was a little over 4.0 per cent, as contrasted with an average normal set of 8.5 per cent during the same period.

The Red Pearmain with 1080 crosses, White Winter Pearmain with 1086 crosses, Gravenstein with 899 crosses, and Tompkins King with 883 crosses failed during two seasons' work to give an appreciable set when used to cross-pollinate the Yellow Bellflower. With only one season's work, the Jonathan, with 736 crosses, the Esopus (Spitzenburg), with 1037 crosses, and the Rhode Island Greening, with 965 crosses, also failed to result in any set of Yellow Bellflower fruits. While the data cannot be taken as showing definite cross-incompatibility, they suggest this to be true in the case of Gravenstein, Tompkins King, Esopus, and Rhode Island Greening.

The pollen germination of the Gravenstein and the Tompkins King was unsatisfactorily low.

TABLE 4

Gravenstein Pollination Experiments (Sebastopol)

Pollen variety	Years inclusive	Number flowers pollinated	Per cent set	Per cent normal set	Per cent pollen germinated
Self-pollinated	1921–23	3593	0.09	6.75	14
Esopus	1921–23	2748	2.60	6.75	81
Delicious	1921–23	3031	9.30	6.75	78
Jonathan	1921–23	2395	2.34	6.75	72
Rhode Island Greening	1922–23	1239	0.00	6.63	50
Yellow Newtown	1922–23	1334	6.20	6.63	73
Yellow Bellflower	1922–23	1715	0.30	6.63	78
Tompkins King	1922–23	1816	0.00	6.63	30
Baldwin	1923	890	0.00	9.10	25

Gravenstein.—The data in table 4 show as the result of three years' work and 3593 self-pollinations, that the Gravenstein is self-unfruitful. This agrees with the work of Lewis and Vincent (1909) in Oregon; and Powell (1902) in Delaware. Morris (1921) in Washington, and Vincent (1920) in Idaho, however, found that when the Gravenstein blossoms were bagged and not actually hand-pollinated, the percentages setting fruit were 5.1 and 3.5, respectively.

The Delicious proved to be the best pollinizer for the Gravenstein, during three years' work as a result of 3031 crossings, giving an average set of 9.3 per cent as contrasted with the normal set of 6.75

per cent. Morris (1921) crossed 99 Gravenstein blossoms with Delicious pollen and found 16 per cent of the blossoms set fruit. Another satisfactory pollinizer was the Yellow Newtown, giving a set comparable with the normal set. Morris (1921), crossing 34 Gravenstein blossoms with Jonathan pollen, found that about 18 per cent set fruit, but crossing 57 Gravenstein blossoms with Esopus found that none of them set fruit. Vincent (1915) also found the Jonathan was cross-fruitful upon the Gravenstein.

The Rhode Island Greening, Yellow Bellflower, Tompkins King, and Baldwin appeared to be cross-incompatible with Gravenstein.

The Gravenstein did not produce abundant pollen, which, moreover, lacked viability, as is shown by the low average germination percentage of 14.0. It appears that the self-unfruitfulness and the cross-incompatibility with other varieties may be due in part to this. With the pollen of the Tompkins King and the Baldwin used in cross-pollinating the Gravenstein, the germination was also unsatisfactorily low, being 30.0 and 25 per cent, respectively.

White Winter Pearmain.—The two years' data in table 5 show the White Winter Pearmain to be self-unfruitful. This agrees with the work of Auchter (1922), Morris (1921), and Vincent (1920). The best pollinizer of the White Winter Pearmain seemed to be the Red Pearmain, although the set resulting was about one-half that of the normal set. The Yellow Bellflower and the Yellow Newtown, when used as pollinizers, were both inter-fruitful with the White Winter Pearmain.

TABLE 5

WHITE WINTER PEARMAIN POLLINATION EXPERIMENTS (Watsonville)

Pollen variety	Years inclusive	Number flowers pollinated	Per cent set	Per cent normal set	Per cent. pollen germinated
Self-pollinated	1920–21	940	0.00	11.32	72
Yellow Bellflower	1920–21	771	2.12	11.32	71
Yellow Newtown	1920–21	943	1.71	11.32	78
Red Pearmain	1920–21	1479	5.58	11.32	63

Tompkins King.—The data from two years' work, as shown in table 6, indicate that the Tompkins King is self-unfruitful, as reported by Lewis and Vincent (1909), and Morris (1921). Auchter, however, employing blossoms covered but not actually hand-pollinated, reported that in Maryland the Tompkins King was self-fruitful. The germination tests indicated a somewhat low viability of the Tompkins

King pollen and markedly low viability or imperfect pollen for the Gravenstein. The Jonathan, of the varieties tested, appeared to be the best pollinizer for the Tompkins King.

TABLE 6

TOMPKINS KING POLLINATION EXPERIMENTS (Sebastopol)

Pollen variety	Years inclusive	Number flowers pollinated	Per cent set	Per cent normal set	Per cent pollen germinated
Self-pollinated	1922–23	1990	0	27.6	30
Gravenstein	1922–23	1349	0	27.6	8
Rhode Island Greening	1922–23	853	0	27.6	67
Yellow Bellflower	1922–23	1411	1.7	27.6	78
Jonathan	1922–23	1072	14.1	27.6	73
Yellow Newtown	1923	359	0	18.9	70

Red Pearmain.—The data in table 7 indicate that the Red Pearmain is self-unfruitful, and that the pollen of Yellow Bellflower, Yellow Newtown, and White Winter Pearmain is cross-compatible with the stigmas of Red Pearmain. While the sets of Red Pearmain pollinated with Yellow Bellflower and Yellow Newtown were less than the normal set, that resulting from White Winter Pearmain pollen was in excess of the normal set.

TABLE 7

RED PEARMAIN POLLINATION EXPERIMENTS (Watsonville)

Pollen variety	Years inclusive	Number flowers pollinated	Per cent set	Per cent normal set	Per cent pollen germinated
Self-pollinated	1920–21	306	0.19	7.16	63
Yellow Bellflower	1920–21	893	3.57	7.16	70
Yellow Newtown	1920–21	890	2.65	7.16	67
White Winter Pearmain	1921	676	8.89	7.22	74

Esopus (*Spitzenburg*).—The data of three years in table 8 indicate that the Esopus (Spitzenburg) is partially self-fruitful. This agrees with the work of Lewis and Vincent (1909). Morris (1921) and Waugh (1898) likewise obtained data which showed a tendency for the variety to be self-fruitful. Vincent (1920) and Waite (1899), however, appeared to find it self-unfruitful under Idaho and New York conditions, respectively. The pollen of Gravenstein, as a result of three seasons' work, was shown to be cross-incompatible upon Esopus (Spitzenburg) stigmas. The Gravenstein pollen, however, gave a low

germination test. Both the Jonathan and the Delicious pollen gave exceptionally high sets, 55.5 and 36.4 per cent, respectively, as contrasted with the normal set of 11.3. Lewis and Vincent found the pollen of Jonathan to be highly compatible upon the stigmas of Esopus (Spitzenburg) and Morris found this was true for both Jonathan and Delicious pollen upon Esopus (Spitzenburg) stigmas.

TABLE 8

Esopus (Spitzenburg) Pollination Experiments (Sebastopol)

Pollen variety	Years inclusive	Number flowers pollinated	Per cent set	Per cent normal set	Per cent pollen germinated
Self-pollinated	1921–23	1037	4.4	20.5	85
Gravenstein	1921–23	1004	0.1	20.5	12
Jonathan	1921	632	55.5	11.3	70
Delicious	1921	730	36.4	11.3	85

Additional Varieties.—The Rhode Island Greening, Jonathan, Delicious, and Baldwin were in each case self-pollinated and cross-pollinated with Gravenstein. The data are given in table 9. The work of two years with Rhode Island Greening, Jonathan, and Delicious indicate that these varieties are self-unfruitful.

The data obtained with the Delicious agree with the work of Vincent (1920), Morris (1921), and Crandall (1922). The data with the Jonathan agree with the findings of Lewis and Vincent in Oregon and Morris in Washington. Vincent in Idaho, and Wicks (1918) in Arkansas, however, seemed to find the Jonathan partly self-fruitful. Crandall (1922), Gowan (1920), Lewis and Vincent (1909), Vincent

TABLE 9

Additional Pollination Experiments

Variety pollinated	Pollen variety	Years inclusive	Number flowers pollinated	Per cent set	Per cent normal set	Per cent pollen germinated
Rhode Island Greening	Self-pollinated	1922–23	582	0	9.8	43
Rhode Island Greening	Gravenstein	1922–23	449	0	9.8	12
Jonathan	Self-pollinated	1921–23	600	0.4	28.4	70
Jonathan	Gravenstein	1922–23	461	0	28.4	12
Delicious	Self-pollinated	1922–23	426	0	22.0	57
Delicious	Gravenstein	1922	150	0	9.1	15
Baldwin	Self-pollinated	1923	209	7.1	19.8	15
Baldwin	Gravenstein	1923	99	0	19.8	10

(1920), Waite (1899), Waugh (1898), and Sax (1922) found the Rhode Island to be self-unfruitful, although Morris found it partially self-fruitful.

The data in table 9 indicate that the Baldwin is self-fruitful. This agrees with the work of Gowen, and Lewis and Vincent. Morris, Auchter (1922) and MacDaniels (1926) also found the Baldwin partly self-fruitful. Waugh and Sax, however, found the Baldwin self-unfruitful, although Waugh simply bagged the blossoms without actually applying the pollen.

The pollen of Gravenstein appeared to be cross-incompatible with each of the four varieties. The Gravenstein pollen viability was low, although this was also true of the Baldwin pollen, which gave a set upon Baldwin stigmas of about 7 per cent.

SUMMARY

1. The use of bees as a means of effecting pollination in an apple orchard greatly increased the set of fruit when contrasted with the normal set.

2. Cross-pollination increased the set of fruit, even with a self-fruitful variety like the Yellow Newtown.

3. The actual application of the pollen by insects or by hand seemed necessary to insure pollination of Yellow Newtown and Yellow Bellflower blossoms.

4. In the case of these two varieties, the method of bagging or enclosing unemasculated blossoms with mosquito-bar to determine self-compatibility or self-incompatibility seemed unreliable.

5. It seemed advisable to enclose emasculated Yellow Newtown or Yellow Bellflower blossoms in paper sacks in order to lessen the drying out of the wounded floral parts remaining and to prolong the period of receptivity. There was no evidence, however, to indicate the advisability of bagging to exclude chance pollination of emasculated flowers.

6. Under the conditions of the experiment, the Yellow Newtown, Esopus (Spitzenburg), and Baldwin were self-fruitful.

7. The Yellow Bellflower, Gravenstein, White Winter Pearmain, Tompkins King, Rhode Island Greening, Delicious, Red Pearmain, and Jonathan were considered self-unfruitful.

8. The Gravenstein did not satisfactorily cross-pollinate any of the varieties tested. This appeared to be the result of defective and non-viable pollen, as determined by germination tests and by microscopic examination of the pollen grains.

9. The pollen of Tompkins King, Esopus, and Rhode Island Greening upon the stigmas of the Yellow Bellflower; of Rhode Island Greening, Thompkins King, and Baldwin upon the Gravenstein; and of Rhode Island Greening and Yellow Newtown upon the stigmas of Tompkins King, did not result in satisfactory sets of fruits.

10. The Yellow Bellflower, Red Pearmain, and the White Winter Pearmain were considered good varieties for pollinating the Yellow Newtown; the Yellow Newtown and Delicious for the Yellow Bellflower and for the Gravenstein; the Red Pearmain for the White Winter Pearmain; the Jonathan for the Tompkins King; the White Winter Pearmain for the Red Pearmain; and the Jonathan and Delicious for the Esopus (Spitzenburg).

11. The pollen of certain varieties was considered as partially cross-compatible upon the stigmas of certain flowers but not sufficiently so for the cross-pollination of commercial plantings. This was true of Esopus and Jonathan pollen upon the stigmas of Gravenstein; the Yellow Bellflower and Yellow Newtown upon White Winter Pearmain; the Yellow Bellflower upon Tompkins King; and Yellow Bellflower and Yellow Newtown pollen upon Red Pearmain stigmas.

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